Antennas

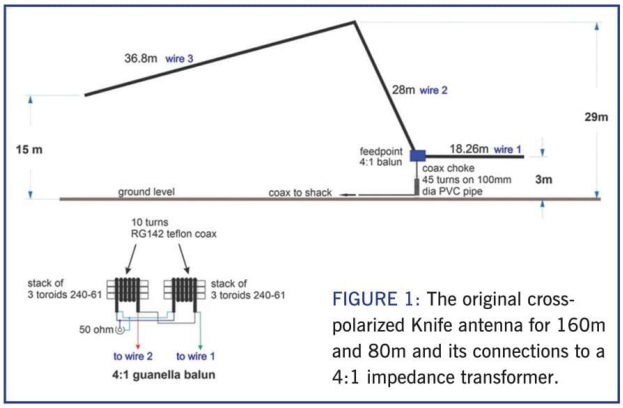

FIGURE 1: The original cross-polarized Knife antenna for 160m and 80m and its connections to a 4:1 impedance transformer.

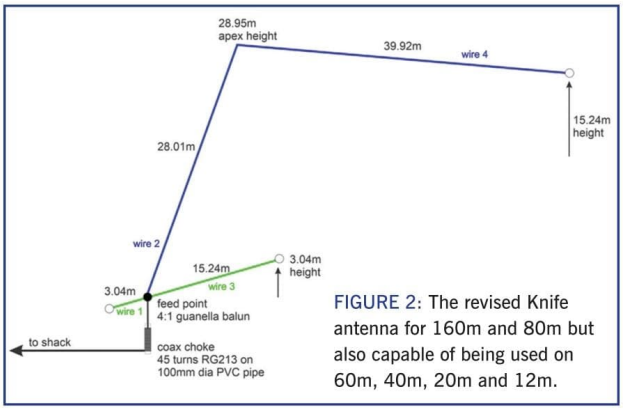

FIGURE 2: The revised Knife antenna for 160m and 80m but also capable of being used on 60m, 40m, 20m and 12m.

Both of us enjoy the excitement of the HF bands but we have long had a strong preference for the lower frequencies. As a result, a lot of our antenna experimentation since we became licensed has been on 160m, 80m and 40m, with the goals of chasing rare DX and high scores in world-wide DX contests.

Introduction

We both have used just about every kind of wire antenna on these bands, from single-band dipoles, delta loops and quarter-wave verticals to sophisticated beam designs. However, even for us in semi-rural Western Australia, with Steve living on a fifth of a hectare and Kevin on one hectare, space is ultimately an issue. Therefore, having a single, highly-efficient, DX antenna, which will work well on at least two of these 'low-bands', is a long-standing aim for us. To achieve this goal, and bearing in mind that our poor ground conductivity means purely vertically-polarised antennas do not work well, we have concentrated on getting a mostly horizontally polarised wire antenna as high in the air as possible.

This wire antenna is usually mounted on top of a two- or three-section ex-commercial telescopic tower, supported over the top of a multiband HF Yagi antenna or quad antenna by a home-made, lightweight extension pole made of aluminium tube and fibreglass, six to ten metres in height. The top of this pole then either has a small pulley attached to it (to allow the hoisting of the wire antenna by means of a halyard) or a UV-proof PVC insulator tied to it by a short length of Dacron rope to support the wire antenna. In this manner, putting our Yagi antennas or quad antennas at around 20m above the ground (a full wave on the 14MHz band to take advantage of ground gain, and sufficient height above houses, garages, sheds, etc), the extension has enabled us to put the centres of our low-band wire antennas about 27m to 30m above the ground.

Until ten years ago, these antennas were generally half-wave dipoles (for 160m, 80m and sometimes 40m on a common coaxial-cable feeder via a ferrite choke balun) or doublets (cut for 160m, the lowest band we wanted to use) and fed with open-wire feeder, usually via a balanced antenna tuning unit (ATU). The first option was the simplest, allowing us to change bands without retuning the ATU but the weight of a balun capable of taking the VK power limit of 400W put a severe strain on the extension pole's fibreglass top section and guying six separate dipole halves was a nightmare.

The second option also had strong disadvantages. Keeping an open-wire feeder away from the HF Yagi antenna or quad antenna and the tower was a major headache; and balanced ATUs took a lot of work to make and required constant, time-taking adjustments after changing frequency. On the commercial side, Palstar do make a very nice 'BT1500A' balanced antenna tuner for about US$995 but this is a manual tuner. The company's 'HF-AUTO' auto tuner was a potential solution but this is currently US$1,695. Also complicating the use of open-wire feeders is the need to have an open-wire feeder length that presents a medium impedance (say up to a couple of hundred ohms) to the ATU on all the bands on which the doublet antenna is to be used in order that the ATU tuning isn't too critical. The 'rule of thumb' to achieve this (on harmonically-related bands such as 160, 80 and 40m) is to use a length of open-wire feeder that is an odd multiple of electrical eighths of a wavelength on the lowest band. On 160m (say, 1.825MHz) this means, assuming a 0.98 velocity factor, that one multiple is going to be about 20.55m (too short for a 27m high antenna) and three is 61.65m (a lot of open-wire to put up).

A decade or so ago, Steve had a 20m/15m/10m three-element Yagi antenna, above which he could just about get an open-wire feeder to connect to a 160m half-wave doublet antenna. With the cost of having two children at university, commercial tuners were out so he built himself a parallel-tuned, link-coupled, tuner mostly from his junk box, ran 61.65m of open-wire feeder all around his back yard and put up with several-minute-long band changes. However, Kevin got creative and took another path; he decided to feed a single 160m half-wave wire as an off-centre fed (OCF) antenna to remove the mess at the top of the tower.

The key to doing this was that the shorter part of the antenna would be used like a counterpoise, running a few metres above the ground. Not only that but the heavy 4:1 transformer balun and accompanying (and even heavier) choke balun, necessary to remove the common-mode earth and coaxial-cable-braid currents which occur because of the unbalanced feed,

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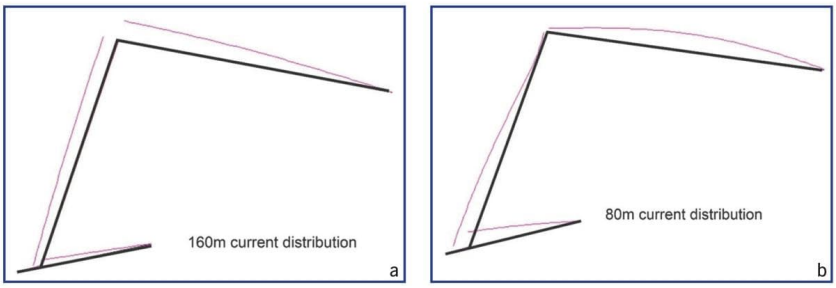

FIGURE 3: The current distribution of the Knife antenna on (a) 160m and (b) 80m.

could be mounted on a small platform at the same height as the antenna's counterpoise. With the 50Ω coaxial cable feeder used (which also made up the choke balun), the internal ATUs on his transceiver and linear were perfectly adequate to reduce the VSWR to 1:1.

This is the Knife!

The prototype OCF dipole Kevin made is shown in **Figure 1**. This was built in a hurry a few days before the CQ WW CW 2014 contest to use on 160m and 80m. Originally, the vertical section (wire 2) was only 21m high, so the horizontal section (wire 3) was around 43.8m long to give resonance on (roughly) 1.8MHz and 3.6MHz. On 160m the current maximum of the antenna, which we now call the Knife, is at its apex (ie the junction of wire 3 and wire 2). The antenna offers a mix of horizontal and vertical radiation on both bands and is more or less omnidirectional on 160m, with the maximum radiation on 80m occurring broadside to it. Wire 2 slopes about 30° to the vertical, which we have found in practice is about the maximum it is possible to slope a wire while retaining optimum vertical polarisation from it.

The Knife was a great success during the CQ WW CW, producing excellent scores and Kevin went on to use it as his 160m/80m antenna for the next decade, extending the vertical wire to 28m as shown in Figure 1 (and consequently shortening the horizontal wire to 36.8m). A half-sized version of the OCF was later developed covering six bands, which we called the Pocketknife antenna and was described in our December 2024 Antennas column.

Sharpening the Knife

Kevin found the original Knife design also had a fair match on 30m without an ATU but when it came to 40m, the VSWR was too high to be usable. However, as he already had a switchable and rotatable 40m 2-element wire Yagi, this wasn't a problem. Both of us continued using our 160m half-wave antennas with their apexes at 27m (90 feet) for the next decade, with Kevin's fed as an OCF and Steve's as a doublet, obtaining very similar successful results. Then Steve's old tower had an accident following a cyclone and, after a rebuild involving Kevin donating a similar tower to Steve, the former reverted to using his favoured (and larger) quad antenna. Unfortunately, running open-wire feeder over the top of the quad then proved more than challenging and resulted in several high-altitude 'rat's nests' of wires.

After a few years of using a 160m doublet at half the old height by stringing it under the quad, Kevin's low-band dominance over Steve got to the point that something had to be done. Steve knew that Kevin's clever OCF Knife design could be used at his QTH to restore the lost height but he needed it to work on 40m as well. This is where having a very good friend who can use EZNEC is extremely useful and Steve had on his side that Kevin's CW operating skills were so vastly superior to his own, he was not going to be a threat to Kevin in terms of contesting or DXing. After a few coffees and cakes at our local café (bought by Steve, of course), Kevin was at work on EZNEC and soon came up a revised Knife design (**Figure 2**). Steve has since built the 160m/80m/40m version and is waiting on some fine days to finish the installation.

The important aspect of the Knife design is its weight, which is purely that of the lightweight aluminium electric-fence wire it is made from, and there is subsequently virtually no bending or strain on the fibreglass top of the extension pole. With Steve's previous doublet in place, the weight of its open-wire feeder was enough to bend the fibreglass pole as though it had hooked a very large fish. This also reduced the antenna's overall height and subsequently caused its wire and feeder to get tangled up with the quad antenna. It is the combination of the Knife antenna having only a relatively-small feeder weight, the use of light-weight wire and the light-weight tower extension that has enabled Steve to put a full-size 160m half wave of wire in the air at this height over the quad antenna.

In the revised version of the Knife put up by Steve (Figure 2), the vertical(ish) section (wire 2) is sloping at about 45° to the vertical, which means the antenna produces less vertically-polarised radiation than Kevin's. However, its highest current point is at its highest point above the ground (and, as regularly mentioned in this column, our very-poor ground conductivity does not favour vertical polarisation). **Figure 3a** and **Figure 3b** show the current distribution of the Knife antenna on 160m and 80m.

Construction

The revised Knife antenna is a cross-polarised antenna designed to cover 160m and 80m with a relatively-good match (under 2:1) to RG-213/LMR-400/LL 400 50Ω coaxial cable. The last 10m of wire at the far end of the horizontal(ish) section (wire 4) can be dropped down vertically so the Knife fits into a roughly 30.5m (100 feet) long space. EZNEC shows that the antenna also has an acceptable match on 60m, 40m, 20m

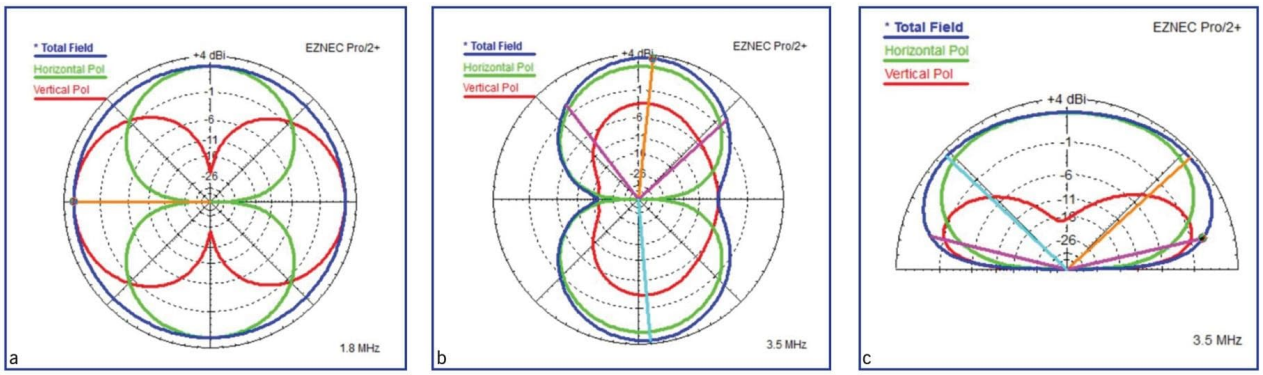

FIGURE 4: Radiation patterns of the Knife antenna, illustrating its cross-polarisation, (a) on 160m, (b) and (c) on 80m.

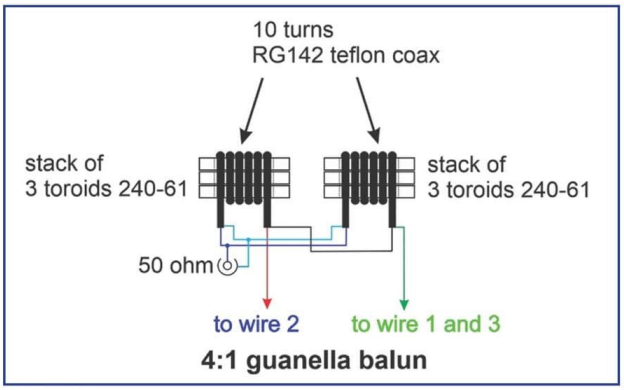

FIGURE 5: The circuit diagram of the revised Knife's Guanella 4:1 impedance transformer, and connections to antenna and counterpoises.

and 12m, which is a useful bonus. No radials are required, just two short counterpoises (wire 1 and 3 in Figure 2) which are about 3m above the ground. The Knife antenna requires a mast or a tree with a height of about 15m at the far end. At the near end, the antenna could be supported by another mast of similar height or by a Dacron rope from your house's chimney stack or roof peak. Both the antenna and counterpoises are made from our usual 2mm bare aluminium electric-fence wire.

Both versions of the Knife antenna provide a very-compact antenna for 160m, with an omnidirectional cross-polarisation; see the azimuth radiation pattern in **Figure 4a**. On 80m it again shows cross-polarisation in azimuth (**Figure 4b**), and has a very nice broadside elevation pattern (**Figure 4c**). The revised Knife antenna's ability to provide matches over six LF/HF bands are because of the use of a 4:1 impedance transformer at the feed point, two separate counterpoises fed in parallel and a very large coaxial feed-line choke. If the antenna is built in the manner described here, it should readily take the UK power limit of 1kW output.

Balun and choke

The key to the Knife antenna's performance is the large Guanella-type 4:1 impedance transformer (see the circuit in **Figure 5**), built in an IP-65-rated box. The two pairs of three FT-240-61 ferrite rings are held in place in the box using hot-melt glue from a gun. We use 6mm stainless-steel hardware and SO-239 or N-type connectors, as is usual in our previous antenna designs. A photo of Kevin's original balun is shown in **Figure 6**. Using a relatively-large box means the transformer has plenty of air around it.

Kevin's 4:1 transformer used in the Knife antenna provides a relatively-good match on all bands from 1.8MHz to 50MHz and is the same one used in our earlier Pocketknife antenna. However, in common with all OCF antennas (including the historical W3EDP so-called end-fed antenna), it also requires a very good feed-line choke to prevent RF currents and noise from flowing on the outer braid of the coaxial feeder and ending up in our radio shacks. We have both experimented with using ferrite and coaxial-cable chokes with the Knife antenna. We found that a large coaxial choke (ie one with many turns) to be the most efficient configuration. Seeking to save weight, Steve's original, large ferrite-ring-cored 1:1 choke saturated with 400W of RF power, causing the antenna's VSWR to become very high. When he investigated by touching the choke, it was so hot it burnt his fingertips. After Steve changed to using Kevin's coaxial choke described below, this was as cool as a cucumber and the VSWR was steady.

The choke consists of 45 turns (15m or so) of the RG-213/LMR-400/LL 400 feeder wound on a piece of 100mm diameter PVC water pipe. Note the white-coloured pipe should be used as the grey-coloured pipe contains some metal reinforcement and will heat-up, drastically reducing the efficiency of your antenna. If in doubt, cut a small piece off your intended pipe and put it in the microwave for 40s or so; if it gets hot, find a different piece of pipe. The choke can be suspended by Dacron rope about a metre above the ground between a couple of star pickets, connected to the 4:1 impedance transformer which is mounted about 3m above the ground. In Steve's case, the impedance transformer box sits on a corner of his garage roof.

FIGURE 6: Kevin's prototype 4:1 impedance transformer.

Keeping VSWR in perspective

As covered in Kevin's column last month, one of the most annoying aspects of modern amateur radio is the obsession with an antenna's VSWR having to be reduced to 1:1. Practically the only important thing about the VSWR is that the transmitter/transceiver is able easily to deliver power into an antenna without malfunctioning (ie blowing up its PA). Much more important in terms of antenna performance are the pattern, gain and height of the antenna.

Let us consider the VSWR loss on a 28m length of Belden 8267 (RG-213) 50Ω coaxial cable **[1]** on 3.5MHz and 28MHz, using the famous CO8TW coaxial cable calculator **[2]**. This length is chosen as it could typically be used as the cable run from a radio shack to the Knife's feed-point. Let's take the example of 3.5MHz. The actual cable loss for a 28m length of Belden RG-213 is 0.33dB. If the VSWR on our Knife antenna on 80m is, say, 2.5:1, this only adds an extra loss of 0.137dB. As you can see, the VSWR loss is considerably less than the cable loss of the cable. Most modern transceivers are fitted with built-in antenna tuning units (which are really 'antenna matching units') that can readily cope with a 2.5:1 VSWRs on an antenna feeder. Solid-state linear amplifiers like the SPE Expert series can be supplied with built-in antenna matching units. If you use a valve linear amplifier then an appropriately-rated T-match 'tuner', either commercial or home-made, is fine for this purpose.

Conclusions

The original Knife antenna is an excellent cross-polarised antenna, with a proven DX performance on 160 and 80m from Western Australia. As a bonus, the revised Knife antenna also covers the 60, 40, 20 and 12m bands, and should be able to be matched by a transceiver's built-in antenna tuner. Both versions can fit into around a 30.5m span if some of the far end is dropped down vertically and have less visual impact than a multi-band doublet as their coaxial feeders run along the ground. They are also much easier to keep in the air than a doublet because of their much-lighter weight and lack of a centrally-located open-wire feeder. While the antenna may be too large for some suburban gardens, it may be suitable for those who are lucky enough to have sufficient space and are serious about contesting and DX working on the 'low-bands'. No radials are involved, just two short counterpoises.

References

[1] Belden 8267 (RG-213 losses) – see belden.com/products/cable/coax-triax-cable/50-ohm-coax-cable/8267

[2] CO8TW coaxial loss calculator – see qsl.net/co8tw/Coax_Calculator.htm